1.0 INTRODUCTION

1.1 TERS History

Texas Environmental Resource Stewards (TERS) was established by various state and federal resource agencies in July 2002 to create greater interagency collaboration on identifying and supporting joint priorities in Texas. Leaders from the U.S. Environmental Protection Agency (EPA), U.S. Army Corps of Engineers (USACE), U.S. Fish and Wildlife Service (FWS), Federal Highway Administration (FHWA), Texas Commission on Environmental Quality (TCEQ), Texas Parks and Wildlife Department (TPWD), Texas Department of Transportation (TXDOT), and the Texas Governor's Office met to develop a vision and objectives for TERS. Other target participants, such as the General Land Office (GLO), Texas Water Development Board (TWDB), Texas Historical Commission (THC), Texas Department of Agriculture, U.S. Forest Service (USFS), and non-governmental organizations (NGO's), such as The Nature Conservancy of Texas (The Conservancy) were also identified as possibly having an interest in supporting the TERS vision and goals. The Conservancy was subsequently asked to participate because of its expertise in producing ecoregional portfolios of important conservation areas.

Participating agencies identified common interests and target activities for collaborative ecosystem evaluation and management in Texas. Common interests and uses included identification of ecologically important areas (wetland, aquatic, and terrestrial) to be targeted for avoidance, minimization of impacts, or compensatory mitigation (enhancement, preservation, or restoration); "streamlining" of regulatory processes; generation of additional data to support regulatory decisions; early assistance with National Environmental Policy Act (NEPA) planning and analysis, project development and review; greater collaboration on environmental planning and public outreach; analysis of cumulative impacts (also including direct, indirect, and secondary impacts); preservation and improvement of surface water, ground water, and air quality; identification of ecologically important habitats (wetland, aquatic, terrestrial, endangered species); and providing improved indicators of biodiversity health and ecosystem functionality (including fragmentation effects). Streamlining, as defined in this report, is a cooperative and coordinated process that assures timely, cost effective, and environmentally sound planning and project development based on concurrent, multi-agency review. Executive Order (EO) 13274, Environmental Stewardship and Transportation Infrastructure Project Reviews, suggests agencies take actions to expedite environmental reviews and permit decisions specifically for transportation projects.

The following vision was developed for TERS:

> Improve mutual understanding of agency needs and expectations.
>
> Use collective knowledge and expertise to broaden perspectives and support decision-making affecting regional environmental, economic and societal policies, issues, and trends.
>
> Strive for synergism, so that the total effect is greater than the sum of individual agency efforts.

The initial goals of TERS were to identify ecologically important areas, identify potential mitigation areas, and streamline regulatory processes. The TERS agency representatives chose to focus solely on environmental and ecological conditions, not historical and cultural resources. This report is the initial step in meeting the first TERS goal: the ecological assessment and identification of ecologically important resources in Texas.

1.2 Texas Ecological Assessment Protocol (TEAP) Goals

The approach to achieving the TERS vision was to identify and collaborate on common priorities using an ecosystem approach to organize strategies that achieve effective and measurable environmental results, and to jointly communicate the results to the public. The TEAP is the method the TERS Steering Committee agreed to (1) develop a scientifically valid, ecosystem-based process for Texas; (2) apply this process to existing available data and information through the use of Geographical Information Systems (GIS); and (3) demonstrate the process for identifying ecologically important resources throughout Texas. TERS participants were asked to identify potential uses for the TEAP within each agency. However, at the present time, no specific commitments or plans for the TEAP have been made.

The TEAP is a screening level, rapid assessment tool using existing electronic data available statewide. The TEAP is an "ecoregional" assessment, applied to an entire state. Therefore, it is general in nature and design. It is a planning tool and screening-level assessment that should lead users to progressively narrow the scope of analysis. It is not an all-encompassing predictive model for each land cover type, species, etc.

The potential intended use of the results of the TEAP include: 1) use in the NEPA planning process (scoping, alternatives development, etc.), 2) use in streamlining the authorization process for large projects (such as transportation) by narrowing the study corridor necessary for further field investigation, and 3) use in mitigation discussions to avoid ecologically important areas, minimize impacts to those areas, and compensate for unavoidable impacts. This list of intended uses is not exhaustive, nor all inclusive. The TEAP is not designed to take the place of agency policies and procedures. It is a supplemental information tool aiding in agency decision making. The initial TEAP product is a CD with the three main layers and composite layer data in GIS format. The final version of this report will be included on the CD.

1.3 Background

1.3.1 Geographical Information System (GIS)-Based Assessments

GIS is used in the development of assessment and geospatial screening tools not only because of its spatial data visualization abilities (i.e., maps of different data layers, coverages, landscape level, etc.), but also because of its modeling and analysis functions, including landscape metrics (e.g. FRAGSTATS), and other calculations such as population density, hydrological function. Given the direction of the TERS executives, it was apparent that GIS would be useful for TEAP. GIS is a vital research and assessment tool (Dale et al. 1994, Treweek and Veitch 1996, O'Neill et al. 1999, Iverson et al. 2001, Clevenger et al. 2002, Ji and Leeberg 2002). When used at the landscape level, GIS can identify and prioritize areas for protection to enable animal movement by evaluating different land management uses (Clevenger et al. 2002).

Regionally-scaled projects, such as those that use the ecoregion (Mysz et al. 2000) or watershed (Dickert and Tuttle 1985, Tinker et al. 1998, Espejel et al. 1999, Steiner et al. 2000a, Steiner et al. 2000b, Serveiss 2002) as a base unit, have become more common with the advent and subsequent increase in the use of spatial analysis tools such as GIS. These tools have inspired scientists concerned about landscape level patterns and their effect on terrestrial and aquatic communities (Steiner et al. 2000a, Jones et al. 2001, H. John Heinz III Center for Science, Economics and the Environment 2002). Assessments, whether landscape- or geographically-based, are more holistic than assessments performed locally, or those based on political boundaries, because of their ability to relate potentially unrelated factors (Miller et al. 1998) and for comparisons at other scales. For example, several geographic units can be aggregated (Montgomery et al. 1995).

Geographically-driven approaches have also been used to analyze environmental problems (e.g. nonpoint source water pollution, regional studies) that do not fit into traditional programs or assessment methods (Boughton et al. 1999, Serveiss 2002,) as well as those problems needing a holistic or comprehensive analysis such as broad assessments like TEAP. Landscape-level assessments also lead to improved intergovernmental coordination and more informed decision-making on regulatory and management initiatives (Steiner et al. 2000a, Serveiss 2002). Better interagency coordination and cooperation are goals of the TERS group.

As with TEAP, most geospatial tools use some sort of criteria or factors to evaluate the data layers used in the assessment (Karydis 1996, Steiner et al. 2000b, Store and Kangas 2001, Xiang 2001). These ranks, or scores, simplify the analysis (Serveiss 2002), normalize disparate data sets onto one nominal scale (Wickham et al. 1999, Clevenger et al. 2002), and provide an easily understandable format to communicate the results to various audiences (Theobald et al. 2000). These ‘scores’ are helpful in comparing various aspects of projects since the ‘score’ represents the relative value of one alternative to another (Abbruzzesee and Leibowitz 1997, Wickham et al. 1999, Steiner et al. 2000b). These scoring systems may represent the difference between an ideal state of the environment and reality (Tran et al. 2002).

1.3.2 Ecoregion Delineation

TEAP uses eighteen ecoregion sections (hereafter referred to as ecoregions) developed by Bailey (1994) as the base unit for calculation. Further details on the process of base unit selection are provided in the Methods chapter. Ecoregions illuminate ecosystem patterns at multiple scales, aiding the visualization of differences between ecosystems. They can be defined as regions of relative homogeneity in ecological systems (Griffith et al. 1999). Most ecoregions include minimally impacted areas that can be used to define reference conditions necessary to provide a basis for comparison to impacted areas. Since multiple areas within an ecoregion are relatively similar, they should respond similarly to stresses or management actions. Thus, ecoregions are appropriate areas for extrapolation of monitoring, including statistical sampling or research results (Bryce et al.1996, Harrison et al. 2000). Ecoregions can be used as reporting frameworks that clarify patterns of environmental data (such as nutrient transport) reflecting both natural and human influences. Griffith et al. (1999) contend that ecoregion frameworks are highly effective tools for accomplishing comprehensive and integrative management approaches due to their depiction of the whole mosaic of ecosystem components - biotic and abiotic, terrestrial and aquatic, including human-related factors that affect water quality and quantity (major components of watershed assessment).

Ecoregions allow the development of management strategies appropriate to regional expectations. They define areas where standardized management practices can be applied after being proven in individual sites or watersheds.

1.3.2.1 Types of Ecoregion Delineation

Bailey (1985, 1987, 1994, 1996) developed a multi-tiered, broad-scale, hierarchical system of ecoregions at a scale of 1:7,500,000 based on numerous environmental variables (Figure 1). The first two tiers are based on combinations of climate, physiography, topography and soils which were used to provide a general description of the ecosystem geography. The ecoregion system can be used to address environmental issues that transcend agency, watershed, and political boundaries and borders. Details of the ecoregion sections in Texas can be found in Appendix A. Other delineations of ecoregions include Omernik (1987, 1995) (Figure 2), Gould (1975) (Figure 3), and Lyndon B. Johnson School of Public Affairs (1978) (Figure 4). The Omernik (1987) system constructs ecoregions based on perceived patterns of a combination of causal and integrative factors including land use, land surface form, potential natural vegetation, and soils (Omernik 1987). Bailey (1994, 1996) and Omernik (1987) plan to merge ecoregion maps. The map of vegetative types of Texas (Gould 1975) provides a checklist and ecological summary of Texas plants (Figure 3).

An interdisciplinary team of scientists and laymen developed a system of classifying Texas into natural regions (Lyndon B. Johnson School of Public Affairs 1978). They recognized that regions distinguished by physiographic or biologic differences could be readily identified by scientists and local citizens, with the goal of preserving elements of Texas' natural diversity (Figure 4).

1.3.3 Ecological Theory Used in TEAP

TEAP divides nineteen individual measures from databases into sub-layers which comprise three separate main layers. These main layers are diversity, rarity, and sustainability.

1.3.3.1 Diversity

The diversity layer shows land cover continuity and diversity in Texas. This layer consists of four sub-layers: (1) appropriateness of land cover, (2) contiguous size of undeveloped area, (3) Shannon land cover diversity, and (4) ecologically significant stream segments.

The diversity layer demonstrates an important fundamental ecological principle: the species-area relationship. The species-area relationship states that larger areas have higher diversity and/or species abundance than smaller areas (Diamond and May 1976, Schafer 1990, Harte and Kinzig 1997). There are several hypotheses to explain the species-area relationship. The one pertinent for TEAP is the habitat diversity hypothesis, which states that increases in the number of types of habitat in an area increases the number of niches able to be filled, therefore larger areas would have more species or land cover types (Jonson and Fahrig 1997). Other species-area hypotheses include island biogeography (MacArthur and Wilson 1967) and the random sample hypothesis (Arrhenius 1921).

1.3.3.1.1 Appropriateness of Land Cover. Appropriateness of land cover describes the predicted natural vegetation under no human influence (Kuchler 1964) and compares it to the current vegetation cover. The rationale for including this measure in the diversity layer is twofold: 1) the area is ecologically stable and resistant to disturbance if pre-settlement vegetation and current vegetation types are the same, and 2) it is a surrogate for species diversity.

1.3.3.1.2 Contiguous Size of Undeveloped Land. Contiguous size of undeveloped land is calculated using the theory that the larger the contiguous area of undeveloped land, the higher the diversity (MacArthur and Wilson 1967, Dale and Haeuber 2000).

There are two similar measures calculated in the diversity and sustainability layers. "Contiguous area of undeveloped area" is entitled and calculated slightly differently in the diversity layer compared to the sustainability layer. In the diversity layer, all undeveloped land cover types that are adjacent to each other are lumped into one polygon. In the sustainability layer, the individual, undeveloped land cover types (that made up this larger polygon in the diversity layer) are calculated separately. In diversity, the question being answered is, "how extensive are the areas of undeveloped land?" In sustainability, the question answered is, "How extensive are the cover types that make up the areas of undeveloped land?"

All adjacent undeveloped land cover is merged into one polygon (e.g., forest adjacent to wetland adjacent to grassland). One polygon could have any number of cover types. For example, one contiguous polygon may consist of three different, undeveloped land cover types. As long as they are all undeveloped and adjacent to each other, the contiguous size of undeveloped land sub-layer is calculated as one polygon (until interrupted by a developed cover type).

1.3.3.1.3 Shannon Land Cover Diversity Index. The Shannon land cover diversity index calculates the diversity, in terms of land cover types, for each of the contiguous polygons calculated in the previous section. The Shannon index is an established method used to measure ecological (species) diversity (richness and evenness) (Begon et al. 1986). It usually calculates the proportion of individuals of a population related to the total number of individuals, but used here to calculate the proportion of land cover types, related to the total number of land cover types. Other ecological diversity measures used in landscape assessment are discussed in Herzog et al. (2001).

The Shannon land cover diversity index does not view land cover diversity the same way as the contiguous size of undeveloped land sub-layer. In general, the Shannon land cover diversity index shows how many specific land cover types there are in these contiguous area polygons and how they are dispersed.

A low value for Shannon land cover diversity index means there are fewer undeveloped land cover types and that they may be clumped, compared to a more evenly dispersed pattern within the geographical boundary. A high value would indicate that there are several undeveloped land cover types that are more evenly dispersed throughout the geographic area. The idea that the Shannon land cover diversity index should increase with less contiguous area is not exactly true because the measures are somewhat independent. Logic indicates that it may be more likely that there are more land cover types in larger areas (polygons), but that is not necessarily the case. For example, there could be a large unbroken tract of desert in west Texas.

1.3.3.1.4 Ecologically Significant Stream Segments. Significant stream segments (Norris and Linum 1999, El-Hage and Moulton 2000a, Norris and Linum 2000a, El-Hage and Moulton 2000b, Norris and Linum 2000b, El-Hage and Moulton 2001) represent natural systems that are increasingly rare habitat and is the aquatic equivalent of the contiguous size of undeveloped land sub-layer. Significant stream segments are ecologically unique areas determined by TPWD based on biological function, hydrologic function, riparian conservation areas, high water quality (including aquatic life and aesthetic value), and threatened or endangered species. TPWD used scientific literature, existing data, and TPWD expertise to identify 228 segments meeting at least one of the criteria listed above.

Stream or river segments are considered significant using five criteria: 1) biological function, where segments display a high level of biodiversity, age, and uniqueness; 2) hydrologic function, where segments perform valuable functions related to water quality, flood attenuation, flow stabilization, or ground water recharge; 3) riparian conservation areas, which includes state and Federal refuges, wildlife management areas, preserves, parks, and mitigation areas; 4) high water quality/exceptional aquatic life/high aesthetic value that represents unique or critical habitat or exceptional aquatic life; and 5) threatened and endangered species/unique communities where segments represent the presence of unique, exemplary, or unusually extensive natural communities.

The ecologically significant stream segment designation is not the same as the ecologically unique stream segment designation. The former has no legal status, but the later represents a statutorily defined legal category. The criteria used for both stream definition types are identical in many respects. The act of officially designating a stream segment as "ecologically unique" is a combined effort of TPWD, TWDB, and the Texas legislature and does not protect the segment from physical degradation. It prevents a state agency from obtaining a fee title or easement that would compromise the ecological value of the designated stream segment. Designation of a segment recognizes the importance of protecting the ecological legacy of Texas' rivers and streams.

1.3.3.2 Rarity

The rarity layer was designed to show rarity of species and land cover in Texas. The rarity layer consists of four sub-layers: (1) vegetation rarity, (2) natural heritage rank, (3) taxonomic richness, and (4) rare species richness.

1.3.3.2.1 Vegetation Rarity. The land cover or vegetation rarity measure is derived from the U. S. Geological Survey (USGS) National Land Cover Dataset (NLCD) and represents rarity of all natural cover types including water and bare rock. Vegetation rarity is a measure of the particular land cover types that are considered rare within each ecoregion.

1.3.3.2.2 Natural Heritage Rank. The Global Heritage Ranking System created by The Conservancy is described as:

> G1, S1, Critically imperiled. Critically imperiled globally (G) (or in the state, S1) because of extreme rarity or because of some factor(s) making it especially vulnerable to extinction. Typically, this rank consists of five or fewer occurrences or very few remaining individuals (< 1,000) or acres (< 2,000) or linear miles (< 10).
>
> G2, S2, Imperiled. Imperiled globally (or in the state, S2) because of rarity or because of some factor(s) making it very vulnerable to extinction or elimination. Typically, this rank consists of 6-20 occurrences or few remaining individuals (1,000-3,000) or acres (2,000-10,000) or linear miles (10-50).
>
> G3, S3, Vulnerable. Vulnerable globally (or in the state, S3) either because they are very rare and local throughout its range, or found only in a restricted range (Even if abundant at some locations), or because of other factors making it vulnerable to extinction or elimination. Typically, this rank consists of 21 to 100 occurrences or between 3,000 to 10,000 individuals.

G4, S4, Apparently secure. Uncommon globally (or in the state, S4), but not rare (although it may be rare in parts of its range, particularly on the periphery), and usually widespread. Apparently not vulnerable in most of its range, but possible cause for long-term concern. Typically, this rank consists of more than 100 occurrences and more than 10,000 individuals.

G5, S5, Secure. Common globally (or in the state, S5), widespread, and abundant (although it may be rare in parts of its range, particularly on the periphery). Not vulnerable in most of its range. Typically, this rank consists of with considerably more than 100 occurrences and more than 10,000 individuals.

1.3.3.2.3 Taxonomic Richness. Taxonomic richness, or the number of rare taxa is another measure of rarity. This sub-layer measures the richness of broad taxonomic groupings; that is, the locations that have a high degree of rarity in multiple taxa, e.g., birds, mammals, reptiles, amphibians, etc. The number of rare taxa (taxonomic richness) indicates taxonomic diversity.

1.3.3.2.4 Rare Species Richness. Another measure of rarity is rare species richness, or the number of rare species per ecoregion. The number of rare species (rare species richness) may indicate the amount of endemism in an area. Rare species may be keystone/umbrella species (Launer and Murphy 1994) or very productive communities or typify a particular ecological community type (Poiani et al. 2001).

1.3.3.3 Sustainability

The sustainability layer describes the state of the environment in terms of stability; that is, how resistant to disturbance an area is, and how capable is the area in returning to its pre-disturbance state, that is, resilience (Begon et al. 1986). For the purposes of this report, sustainable areas are those that can maintain themselves into the future without human management.

Stability has two components: resistance and resilience. Resistance is defined as an ecological community's ability to withstand disturbance (Begon et al. 1986), whereas resilience is the ability of an ecological community to recover from a disturbance (Begon et al. 1986). Highly sustainable ecosystems are able to resist disturbance, but once disturbed can return to the pre-disturbance state within a short time period (resilience) (Begon et al. 1986). The sustainability layer consists of eleven measures that can be loosely grouped into fragmentors: (1) contiguous land cover type, (2) regularity of ecosystem boundary, (3) appropriateness of land cover, (4) waterway obstruction, and (5) road density and stressors: (1) airport noise, (2) Superfund National Priority List (NPL) and state Superfund Sites, (3) water quality, (4) air quality,(5) Resource Conservation and Recovery Act (RCRA) Treatment-Storage-Disposal sites (TSD), corrective action and state Voluntary Cleanup Program (VCP) Sites, and (6) urban/agricultural disturbance.

1.3.3.3.1 Contiguous Land Cover Type. Contiguous land cover is based on the principle that larger areas having similar ecosystem types have greater sustainability. Contiguous area of undeveloped land supports connectivity, the opposite of the isolating effects of fragmentation (Gustafson and Gardner 1996). Larger habitat areas have less edge than smaller habitat areas and therefore, can preserve biodiversity (Lee et al. 2001). Larger areas of contiguous habitat can support large animals or widely-dispersing animals such as carnivores and large ungulates. As these large areas are fragmented, either through direct habitat loss or through insularization, the remaining habitat may not maintain viable population of these organisms (Tigas et al. 2002).

Fragmentation of habitats comprises two ecological effects: 1) loss of habitat, and 2) increased insularization (or isolation) of the remaining habitat (Noss and Csuti 1994). It is a spatial phenomenon that affects landscape continuity (Robinson et al. 1992) and poses some of the most significant challenges to ecologists. It is a major threat to landscape continuity and can disrupt temporal and spatial habitat use by animals (Tigas et al. 2002). The effects of fragmentation have been demonstrated for a variety of taxa: mammals (Brown 1986, Foster and Gaines 1991, Chiarello 1999, Lindenmayer et al. 1999); birds (Askins et al. 1987, Opdam 1991, Walters et al. 1999); reptiles and amphibians (Johnson 1986, Vos and Stempel 1995); and insects (Johnson 1986, Thomas and Harrison 1992, Wahlberg et al. 1996).

1.3.3.3.2 Regularity of Ecosystem Boundary. For all land cover types except open water, conventional ecological wisdom suggests that the smaller the perimeter for a given area, the larger the core interior habitat. It is based on the principle that the least amount of boundary results in the lowest amount of "edge effect" thereby yielding the least disturbance and greatest sustainability of the ecosystem. The reverse is also true; areas with larger perimeters compared to their areas, will have a greater amount of "edge" habitat and less "interior" or core area. The more complex the edge, the more opportunities for negative influences to affect the location. The more negative influences, the less sustainable the location. Habitat edges differ from the interior in their ecological processes (Donovan et al. 1997) and in physical impacts, such as changes in vegetation density, size, shape, matrix habitat, and fragment aggregation. Small patches may have properties similar to the edge throughout.

The measure of regularity of ecoregion boundary reflects the perimeter to area ratios (PAR) of areas of particular land cover types. Ecological theory suggests that perfectly circular or square habitat areas will have higher diversity and/or species abundance compared to linear habitat areas (Game 1980). However, small narrow areas may provide erosion control to riparian areas (H. John Heinz III Center for Science, Economics and the Environment 2002). Habitat edges differ from the interior in their ecological processes (Donovan et al. 1997) including physical impacts, such as changes in vegetation density, size, shape, and matrix habitat (Lidicker 1999). Biological impacts to species (Yahner 1988) are well documented. Edges are transition zones where generalist species thrive. Conventional ecological wisdom concerning “edge” demonstrate that invasive or opportunistic species prefer the types of habitat associated with the “edge,” or the boundary between two habitat types (H. John Heinz III Center for Science, Economics and the Environment 2002). As one moves away from the edge there is a change in species composition (Lee et al. 2001) which can be associated with abiotic factors, such as temperature, humidity, and vegetation structure (McCollin 1998). Unique or rare species typically use “interior” habitat or may need a large amount of habitat as a home range.

There are many examples concerning edge-interior species. For example, cowbirds and other parasitic birds prefer the habitat on the agriculture-forest boundary and prey on birds, such as the black-capped vireo or golden-cheeked warbler, that need a certain amount of habitat away from this boundary, or interior habitat. Many birds, including warblers and red-cockaded woodpeckers require forest interior habitat. Large-bodied animals, such as bears and mountain lions, may need extended habitat areas in which to forage and mate, without the intrusion of urban or agricultural activities (Noss and Csuti 1994). Forest areas adjacent to non forest areas may by more affected by abiotic elements (e.g., wind, heat) and consequently open to invasion by exotic species (H. John Heinz III Center for Science, Economics and the Environment 2002).

It is widely accepted that the nature of patch edge in aquatic and terrestrial systems differs greatly due to high differences in the land cover types (water vs land) and differences in the nature of communities of the interface zones. A more convoluted water/land edge allows for a greater amount of habitat suitable for the species and communities that live (and often can only exist) in these interface zones. At the most general level, this land/water edge differs from the edge between two (or more) terrestrial land cover types because of the difference in the cover type media (i.e. water vs. land). There is less transfer in species, materials and energy between these two patch types (i.e., there is less invasion possible either from water to land or vice versa, and thus less deleterious "edge effect." The term "edge effect" is not widely used in the literature for water/land boundaries compared to the description of dynamics between terrestrial land cover patches.

As habitat areas become more fragmented and insularized, the edge habitat tends to increase and the interior habitat tends to decrease; therefore, impacting the sustainability of rare or unique species. Because of internal modifications and the lack of intact core areas, small patches may have properties similar to the edge. A preference for the edge results in a negative response to habitat area because large habitat areas have smaller PARs than small habitat areas (Cappuccino and Root 1992). Studies describing habitat "shape" are related to edge effects through the PAR (Collinge 1996, 1998, Collinge and Forman 1998). In addition, island biogeographic theory (MacArthur and Wilson 1967) has been used to generate the following "optimum" characteristics for land and species conservation: large circular, undivided sites (or "reserves"), or if the site is divided, then connectivity by corridors (Wilson and Willis 1975, Diamond and May 1976, Burel 1989) based on these shape and "edge effect" theories.

1.3.3.3.3 Appropriateness of Land Cover. Appropriateness of land cover describes the predicted natural vegetation under no human influence (Kuchler 1964) and compares it to the current vegetation cover. The rationale for including this measure in the sustainability layer is that if pre-settlement and current vegetation types are similar then the seed bank is intact and therefore the area can recover from a disturbance more quickly (resilience).

1.3.3.3.4 Waterway Obstruction. The waterway obstruction sub-layer is based on the principle that dams and corresponding reservoirs are interruptions to the continuity of waterways. Waterway obstruction is a surrogate for fragmentation to water bodies. Dams disturb the natural flow regime of a river, turning it into a reservoir and non-flowing system. The river environment, both aquatic and riparian, is fragmented and insularized, thus creating disturbances for the fish, aquatic organisms and plant communities associated with this habitat.

1.3.3.3.5 Road Density. The road density sub-layer is based on the principle that roads fragment the landscape (Abbitt et al. 2000). In general, more roads and larger roads (multilane highways, for example) occur near the population centers and also serve to connect them. The higher the density of roads, the more fragmentation and disturbance occurs to natural communities (Abbitt et al. 2000).

1.3.3.3.6 Airport Noise. The airport noise sub-layer is based on the principle that noise around airports stresses surrounding habitats thereby lowering the quality of wildlife habitat. Airport noise is a disturbance to natural communities based upon the noise level from airplanes and associated activities, maintenance on the runways themselves, and because they serve as a catalyst for development surrounding the airport. Airports with larger runways typically have wider areas of disturbance.

Aircraft noise is known to impact wildlife patterns especially those of birds (e.g., feeding, resting and nesting) and to increase predation on amphibians has been observed. According to the Federal Aviation Administration (FAA), the noise generated by an aircraft is generally determined by the thrust powering the aircraft; the amount of thrust an aircraft needs is proportional to the weight of the plane. That is, the heavier the aircraft, the more thrust it needs and the more noise is produced. Runway length only defines the heaviest aircraft (total weight) that can land and take off. While newer aircraft have shorter runway length take off requirements and reduced noise, many of the older aircraft (e.g., 747 and Lear 25) with high noise potential remain in service. The buffer distance around airports was used as an indication of disturbance due to noise. To estimate the distance, the noise disturbance was assumed to be proportional to the size of the aircraft, and that was proportional to the runway length.

1.3.3.3.7 Superfund National Priority List (NPL) and State Superfund Sites. These are sites where hazardous substances have been released and are, by definition, disturbances or stressors on the natural environment. While efforts are made to minimize the impacts of these sites and to clean up or contain contaminants to acceptable risk level, the release of toxic chemicals may permanently alter natural conditions. These areas and natural areas adjacent to them are less likely to be self sustaining and more likely to require human management for their continued existence. Once clean up efforts have been completed, further development may be restricted or prohibited at portions of those sites where waste has been left in place in order to prevent disturbance of containment areas and subsequent human exposure. For example, future highway or other construction activities at some sites may need to be avoided. However, with proper engineering, many such sites can and have been put to productive use. As a consequence, unique opportunities for low impact restoration of natural or near-natural habitat areas may be available.

1.3.3.3.8 Water Quality. Water quality or the lack of water quality (defined by Clean Water Act (CWA) Section 303(d), as not meeting designated uses) is another stressor on the natural environment. This sub-layer in no way intends to abrogate any obligations or duties assigned by law to TERS participating agencies.

1.3.3.3.9 Air Quality. Air quality can impact ecological communities due to outfall of chemicals or particulates that become incorporated in the soil of food chain. Poor air quality may be due to mobile sources such as the amount of cars or industrial activities, such as petroleum refining. This sub-layer in no way intends to abrogate any obligations or duties assigned by law to TERS participating agencies.

High concentrations of ozone can have negative effects on flora and fauna (H. John Heinz III Center for Science, Economics and the Environment 2002). Ozone can affect water movement, cycling of mineral nutrients, and habitats for various animal and plant species (EPA 2002). Pollutants such as lead, mercury, and others can be transported and deposited in water or soil where they may be incorporated into the food chain. Nitrogen and sulphur can acidify some water bodies, making them uninhabitable for aquatic species (EPA 2002). Acid deposition can leach nutrients from the soil, consequently affecting plant growth and soil fauna, and enhance the movement of potentially toxic heavy metals, such as aluminum. Deposition of nitrogen can cause eutrophic conditions such as algal blooms and decreased oxygen levels, which in turn may result in fish kills.

1.3.3.3.10 RCRA TSD, Corrective Action and State VCP Sites. These sites are typically smaller than Superfund sites. RCRA TSD sites are active facilities where hazardous wastes are managed on site. RCRA corrective action sites are active TSD facilities which have had releases of hazardous substances and are, by definition, disturbances or stressors on the natural environment. VCP sites are inactive facilities contaminated by various pollutants which typically do not qualify for the state or federal Superfund programs and where a third party wishes to conduct a cleanup in order to redevelop the site. While efforts are made to minimize the impacts of these sites and to clean up or contain contaminants to acceptable risk level, the release of toxic chemicals may permanently alter natural conditions. These areas and natural areas adjacent to them are less likely to be self sustaining and may require human management for their continued existence. Once clean up efforts have been completed, further development may be restricted or prohibited at portions of those sites where waste has been left in place in order to prevent disturbance of containment areas and subsequent human exposure. For example, future highway or other construction activities at some sites may need to be avoided. However, with proper engineering, many such sites can and have been put to productive use. As a consequence, unique opportunities for low impact restoration of natural or near-natural habitat areas may be available.

1.3.3.3.11 Urban/Agriculture Disturbance. This sub-layer is based on the principle that activities in urban and agricultural areas generate disturbances (stressors) to surrounding areas. Stressors such as pesticides, fertilizers, and noise are included.

The urban/agricultural disturbance sub-layer is a surrogate for general population disturbance. These "developed" land cover types are not considered in the calculations in the diversity and rarity layers, but are appropriate in this sustainability sub-layer. The sustainability of an ecological community can be impacted by the amount of human activity, such as those related to agriculture (e.g., pesticide use, nutrient runoff, erosion, etc.) and population (e.g., urban activities including roads, cars, urban sprawl, solid waste, Polycyclic Aromatic Hydrocarbon (PAH) runoff, general environmental contamination, etc.) (White et al. 1996, H. John Heinz III Center for Science, Economics and the Environment 2002, Tigas et al. 2002). Urban uses and agriculture also fragment the community and change natural landscape from desired vegetation types (e.g., wetland, forest, etc.) to undesirable vegetation types (e.g., agricultural monocultures, invasive or opportunistic species) (White et al. 1996, Tigas et al. 2002).

1.3.4 TEAP Development

EPA reviewed over twenty applicable studies and protocols throughout the U.S. (Critical Ecosystems Workshop 2002). TERS participating agency representatives were invited to identify studies and methodologies that could be helpful in addressing objectives and to decide on an appropriate protocol. Reviews resulted in the selection of three protocols for further adaptation and development: (1) processes and information developed in the TPWD Land and Water Resources Conservation and Recreation Plan (Texas Parks and Wildlife Department 2002), (2) information generated by The Nature Conservancy of Texas Ecoregional Planning Process (Groves et al. 2000) and (3) EPA Region 5 Critical Ecosystems Assessment Model (CrEAM) (Mysz et al. 2000, White et al. 2003).

1.3.4.1 TPWD Conservation Planning

TPWD has drafted a strategic plan for ecological and recreational resources for both land and water (Texas Parks and Wildlife Department 2002). TPWD performed an ecoregion priority analysis, using three main criteria: conserved status, primary level of threat, and biological value. Conserved status is determined by the percentage of publicly owned land, land owned by non-governmental conservation groups, large local conserved parkland, and the percentage of the ecoregion operated under TPWD management plans. Primary level of threat is determined by comparing the percentage of land converted to urban or agricultural use, fragmentation of agricultural lands and population growth projections. Biological value is determined by total vertebrate species richness, vascular plant species richness or actual number of species occurring in each ecoregion. Over twenty-two categories of data were collected and mapped. Results by ecoregion are summarized in Table 1.

1.3.4.2 The Nature Conservancy Ecoregional Planning Process

The Conservancy's Ecoregional Planning Process applies a planning and validation process that includes GIS-based analysis, field investigations, and ecological expertise as to endangered community types (Poiani et al. 1998, Groves et al. 2000, Poiani et al. 2001). The

Conservancy uses four criteria to identify and select areas of biodiversity significance: occurrence of conservation elements, functionality of those elements, representativeness, and complimentarity. Conservation elements are those species, natural communities, and ecological systems that are chosen as the focus for conservation within an ecoregion. The Conservancy has completed this process, with multiscale mapping of priority ecological areas for Gulf Coast Prairies and Marshes, West Gulf Coastal Plain, Edwards Plateau, Chihuahuan Desert, Upper West Gulf Coastal Plain, and the Southern Shortgrass Prairie in Texas. The Cross Timbers and Southern Tallgrass Prairie and Tamaulipan Thornscrub were scheduled to be completed by June 2003.

The Conservancy process involved field verification of ecological type and because The Conservancy has not completed its process statewide, The Conservancy data and portfolio conservation areas are to be used in the preliminary accuracy assessment of TEAP results.

1.3.4.3 EPA Region 5 CrEAM

The EPA Region 5 CrEAM (White et al. 2003) model incorporated three key criteria based on established ecological theory: 1) diversity, 2) rarity, and 3) sustainability. Twenty geographically referenced data sets were used to develop indicators for these three criteria. All data sets were pre-existing or derived from pre-existing data sets. Because of the differences in data sets, the CrEAM used 25 acres as its smallest unit of measure. Since TEAP modifies the CrEAM, further details are located in the methods section.

The CrEAM fits within the EPA Science Advisory Board (SAB) ecological framework. In 2002, the EPA Science Advisory Board (SAB) Ecological Processes and Effects Committee released a draft framework for assessing and reporting on ecological condition. The purpose of which was to guide practitioners on designing systems to assess and report ecological conditions. The framework also helps investigators to organize and decide what features to measure for a picture of ecological 'health.' Program goals and objectives are used to determine what essential ecological attributes will be used. There are six broad categories and several subcategories under each: landscape condition, biotic condition, chemical and physical characteristics, ecological processes, hydrology/geomorphology, and natural disturbance regimes. The set of six attributes can be used to determine ecological indicators, or characteristics of ecological systems, and specific measures and monitoring data used to determine the indicator, or endpoint. It is a hierarchical structure where measures can be aggregated into indicators and indicators can be aggregated into attributes. The six attributes are independent of program goals and objectives, but serve as a stimulus for practitioners to decide what attributes and subcategories are essential to a project.

Not every attribute category or subcategory is appropriate in every situation; a user must select those attributes from the SAB framework that provide the best measure and analysis of the project objectives. Table 2 shows the SAB ecological attribute categories, subcategories, suggested measure, and corresponding TEAP criterion. The SAB also suggests that the framework aids in designing the assessment and subsequent report in that it should "transparently record the decision tree and professional judgements used to develop it." The TEAP follows this framework since the measures are aggregated into four broad categories which follow the SAB framework of aggregating measures and indicators; therefore, both single 'media' and aggregate effects (ecological, socioeconomic, etc.) can be considered.

The TEAP allows users to analyze ecological condition, project consequences, and suggest mitigation within watersheds or ecoregions. The TEAP also adheres to the SAB framework by being 1) ‘multimedia’; 2) interagency (a repository for coordinating other agencies’ data); and 3) understandable to non-scientists by using an intuitive 0 to 100 decision structure.

The SAB also suggests that reference conditions be defined so that ecological indicators can be compared and later normalized for aggregation. This concept is imbedded within TEAP by using a 0 to 100 ranking structure which serves to normalize disparate criteria values.